Written examination in Operating Systems

February 12th 2024

Last name:	
First name:	
Student number:	

Mit dem Bearbeiten dieser schriftlichen Prüfung (Klausur) bestätigen Sie, dass Sie diese alleine bearbeiten und dass Sie sich gesund und prüfungsfähig fühlen. Mit dem Erhalt der Aufgabenstellung gilt die Klausur als angetreten und wird bewertet.

By attending this written exam, you confirm that you are working on it alone and feel healthy and capable to participate. Once you have received the examination paper, you are considered to have participated in the exam, and it will be graded.

- Use the provided sheets. Do *not* use own paper.
- You are allowed to use a *self prepared*, *single sided DIN-A4 sheet* in the exam. Only *hand-written originals* are allowed, but no copies.
- Do not use a red pen.
- Time limit: 90 minutes
- Turn off your mobile phones!

Grade: _____

Questions:	1	2	3	4	5	6	7	8	9	10	11	12	13	Σ
Maximum Points:	10	6	8	7	7	7	8	8	4	7	6	7	5	90
Achieved Points:														

1.0: 90.0-85.5, **1.3**: 85.0-81.0, **1.7**: 80.5-76.5, **2.0**: 76.0-72.0, **2.3**: 71.5-67.5, **2.7**: 67.0-63.0, **3.0**: 62.5-58.5, **3.3**: 58.0-54.0, **3.7**: 53.5-49.5, **4.0**: 49.0-45.0, **5.0**: <45

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(Question 1)	Points: of 10
1 Point	(1) Describe what swapping i	s.
1 Point	(2) Explain what singletaskin	g is.
1 Point	(3) Describe what half multi-	user operating systems are.
1 Point	(4) Describe the difference be	tween 8 bit, 16 bit, 32 bit, and 64 bit operating systems.
¹ ∕ ₂ Point	(5) Give the maximum amou	nt of memory, a 32-bit architecture can address.
2 Points	(6) Explain why multi-level p 64-bit systems.	aging and not single-level paging is used in 32-bit and
1 Point	(7) Explain the event that ca	uses a page fault exception.
1 Point	(8) Give the name of the best	page replacement strategy and describe how it works.
1 Point	(9) Describe the key message	of Laszlo Belady's anomaly.
¹ / ₂ Point	(10) Give the name of the pag modern operating systems	e replacement strategy that is implemented by most s (Hint: It is not OPT and not random).

Question 2)

Points: of 6

	Give a command that can be used to
$\frac{1}{2}$ Point	(1) modify the permissions of files or directories.
$\frac{1}{2}$ Point	(2) print out the path of the present working directory in the shell.
$\frac{1}{2}$ Point	(3) create a new directory.
$\frac{1}{2}$ Point	(4) create an empty file.
$\frac{1}{2}$ Point	(5) concatenate the content of different files or print out the content of a file.
¹ ∕ ₂ Point	(6) print out lines from the end of a file in the shell.
$\frac{1}{2}$ Point	(7) print out lines from the beginning of a file in the shell.
$\frac{1}{2}$ Point	(8) delete files or directories.
$\frac{1}{2}$ Point	(9) place a string in the shell.
$\frac{1}{2}$ Point	(10) create a link.
$\frac{1}{2}$ Point	(11) search a file for lines, which contain a search pattern.
$\frac{1}{2}$ Point	(12) terminate a process.

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Question 3	3)
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Points: of 8

 $| \frac{1}{2} \text{ Point} |$ (1) Na

(1) Name <u>one</u> persistent data storage.

 $\frac{1}{2}$ Point (2) Name <u>one</u> non-persistent data storage.

 $\frac{1}{2} \text{ Point} \qquad (3) \text{ The storage of computer systems is distinguished into the categories primary,} \\ \text{secondary, and tertiary storage. Give the name of the category or categories the} \\ \text{CPU can access directly.}$

1 Point

(4) Give the name of the category or categories of subtask (3) the CPU can only access via a controller.

1^{1_2} Points (5) Name <u>one</u> example for each category of subtask (3).

- 1 Point (6) Describe what near-line storage is.
- 1 Point (7) Describe what off-line storage is.

2 Points (8) Name <u>one</u> advantage and <u>one</u> drawback of NAND memory compared with NOR memory.

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Quest	tion	(4)
Ques		エノ

Points: of 7

1 Point

(1) Explain the effect when executing this command in the command-line shell:\$ chmod 777 script.sh

1 Point

- (2) Explain the effect when executing this command in the command-line shell:\$ chmod 544 script.sh
- 1 Point (3) Explain the effect when executing this command in the command-line shell: \$ chmod 000 script.sh
- 1 Point (4) Explain the effect when executing this command in the command-line shell: \$ chmod u-x folder

 $\frac{1}{2}$ Point (5) For executing a program written in the language C one requires a(n)...

\Box Booster	
\Box Compiler	

 $\Box \text{ Interpreter} \\ \Box \text{ Mixer}$

 \Box All of them \Box None of them

$\frac{1}{2}$ Point (6) For executing a program written in the language Python one requires a(n)...

Booster	
Compiler	

□ Interpreter
\Box Mixer

 $\Box \text{ All of them} \\ \Box \text{ None of them} \\ \end{cases}$

1 Point (7) Explain the purpose of the Page-Table Base Register (PTBS).

1 Point (8) Explain the purpose of the Page-Table Length Register (PTLR).

	\mathbf{Qu}	estion 5)		Points:	of 7
$\frac{1}{2}$ Point	(1)	Local variables of fur	nctions resi	de inside the	
	1	\Box Data Segment	\Box Stack	\Box Text Segment	
$\frac{1}{2}$ Point	(2)	Call parameters and	return add	resses of functions reside inside	de the
		\Box Data Segment	\Box Stack	\Box Text Segment	
$\frac{1}{2}$ Point	(3)	Variables which get v reside inside the	values assig	gned in global declarations (or \Box Text Segment	itside of functions)
1/ Point	(4)	Environment variable	es of a proc	coss reside inside the	
/2 1 01110	(1)	Data Segment	Stack	Text Segment	
¹ / ₂ Point	(5)	The machine code of	a process	resides inside the	
/2 1 01110		Data Segment		Text Segment	
¹ / ₂ Point	(6)	Command line argun	nents of a r	process reside inside the	
72 1 01110		\Box Data Segment	Stack	Text Segment	
4 Points	(7)	The figure shows the labels (technical term about the content of	structure ns) of the p this data.	of a UNIX process in memory process-related data and the n	r. Fill in the missing nissing information
		dynamic gro		Iast address of the	space

- first address

←

Question 6) Points: of 7 1 Point (1) Describe which information inodes store. 1 Point (2) Describe what a cluster in the file system is. $\frac{1}{2}$ Point (3) Give <u>one</u> example for an absolute path name. $\frac{1}{2}$ Point (4) Name one Linux file system that implements block addressing. $\frac{1}{2}$ Point (5) Name <u>one</u> Linux file system that implements journaling. $\frac{1}{2}$ Point (6) Name <u>one</u> Linux file system that implements extents. $\frac{1}{2}$ Point (7) Name <u>one</u> Windows file system that implements the file allocation table. $\frac{1}{2}$ Point (8) Name <u>one</u> Windows file system that implements journaling. $\frac{1}{2}$ Point (9) Name <u>one</u> Windows file system that implements extents.

 $\frac{1}{2}$ Point (10) Name <u>one</u> file system that implements copy-on-write.

1 Point (11) Describe what the master file table is.

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Question 7)

Points: of 8

1 Point

(1) Explain what a zombie process is.

3 Points

(2) The following C source code creates a child process.

```
1 #include <stdio.h>
 2 #include <unistd.h>
  #include <stdlib.h>
3
 4
5
  void main() {
\mathbf{6}
     int returnvalue = fork();
 7
     if (returnvalue < 0) {</pre>
8
       printf("Error.\n");
9
10
       exit(1);
11
     }
12
     else if (returnvalue > 0) {
       printf("Parent.\n");
13
14
       exit(0);
     }
15
16
     else {
17
       printf("Child.\n");
18
       exit(0);
19
     }
20 }
```

Give the value of the **returnvalue** variable for the child process and for the parent process. In your answer, explain the importance of the return value in the parent process.

2 Points

(3) Name <u>two</u> differences of a child process from the parent process shortly after its creation.

2 Points (4) Describe the consequences if a parent process is terminated before the child process.

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Question 8)

Points: of 8

1 Point

(1) Explain why fairness is a relevant criteria in scheduling.

2 Points (2) Explain the difference between preemptive and non-preemptive scheduling.

1 Point (3) Name the scheduling method that Windows operating systems implement.

4 Points (4) Explain how the scheduling method of Windows operating systems works. (Hint: A schematic diagram may help here!)

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Question 9)

4 Points

Points: of 4

(1) Explain how the Completely Fair Scheduler of the Linux kernel (Kernel 2.6.23 until Kernel 6.5.13) works.
 (Hint: A schematic diagram may help here!)

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Question 10)

Points: of 7

1 Point (1) Describe what a critical section is.

1 Point (2) Describe what a race condition is.

1 Point (3) Describe why race conditions are hard to locate and fix.

1 Point (4) Explain what a system call is.

1 Point (5) Explain what the standard library is and its purpose.

1 Point (6) Explain what a semaphore is.

1 Point (7) Explain what a mutex is.

Points: of 6

Question 11)

6 Points

(1) Perform the deadlock detection with matrices and check if a deadlock occurs.

Existing resource vector = $\begin{pmatrix} 10 & 5 & 7 \end{pmatrix}$

Current allocation = matrix	$\left[\begin{array}{c}0\\2\\3\\2\\0\end{array}\right]$	$egin{array}{c} 1 \\ 0 \\ 0 \\ 1 \\ 0 \end{array}$	$\begin{bmatrix} 0 \\ 0 \\ 2 \\ 1 \\ 2 \end{bmatrix}$	$\frac{\text{Request}}{\text{matrix}} =$	$\begin{bmatrix} 7\\1\\6\\4\\4 \end{bmatrix}$	4 2 5 1 3	3 - 2 0 1 5 -
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Question 12)

Points: of 7

 $\frac{1}{2} Point \qquad (1) Name <u>one</u> sort of inter-process communication that can only be used for processes that are closely related to each other.$

 $\frac{1}{2} Point$ (2) Name <u>one</u> sort of inter-process communication that allows communication over computer system boundaries.

3 Points (3) The figure shows the working principle of signaling, a technique that is used to specify an execution order of critical sections of processes.



Describe where you see room for improvement in terms of CPU utilization.

2 Points (4) Explain <u>one</u> possible way of implementing the signaling technique shown in subtask (3) in Linux.

- 1 Point
- (5) Name a technique for process synchronisation, which has less drawbacks than signaling shown in subtask (3).

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Points: of 5

Question 13)

2 Points

(1) The figure shows the working principle of a synchronisation technique that ensures that the execution of critical sections does not overlap and does not specify the execution order of the critical sections.



Explain <u>one</u> possible way of implementing the signaling technique shown in this subtask in Linux

 $\frac{1}{2}$ Point (2) Name <u>one</u> sort of inter-process communication that operates bidirectional.

 $\frac{1}{2} \frac{1}{2} \frac{1}$

(4) Explain the meaning of the lines and columns in the file /proc/buddyinfo.

\$ cat	; /p	proc/b	uddyinfo											
Node	0,	zone	DMA	1	1	1	0	2	1	1	0	1	1	3
Node	0,	zone	DMA32	208	124	1646	566	347	116	139	115	17	4	212
Node	0,	zone	Normal	43	62	747	433	273	300	254	190	20	8	287

2 Points